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MEASURING
PUBLIC WORKS PERFORMANCE

BY

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A REPORT PRESENTED TO THE GRADUATE COMMITTEE OF THE DEPARTMENT OF CIVIL ENGINEERING IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ENGINEERING

UNIVERSITY OF FLORIDA

SUMMER 1983

T217461

TABLE OF CONTENTS

		Page
PART ONE:	THE PRINCIPLES OF PERFORMANCE MEASUREMENTS	1
CHAPTER 1	INTRODUCTION	1
	1.1 Why Peformance Measurement	1
	1.2 What Should be Measured	2
CHAPTER 2	ELEMENTS OF PERFORMANCE EVALUATION	4
	2.1 Traditional Approaches	4
	2.2 A Systems Perspective	5
	2.2.1 Environmental Factors	5
	2.2.2 Inputs	6
	2.2.3 Program Operation Variables	6
	2.2.4 Outputs	7
	2.2.5 Linking Variables	7
	2.2.6 Outcomes	8
CHAPTER 3	PROCESS MEASURES	9
	3.1 Productivity Indicators	9
	3.2 Outputs	9
	3.3 Inputs	10
	3.4 Efficiency Indexing	11
	3.5 Complex Indices	12
	3.6 Multifactor Measurement	16
	3.7 Pitfalls	16
CHAPTER 4	EFFECTIVENESS MEASURES	18
	4.1 Meeting Objectives	18
	4.2 Specifying Outcomes	19
	4.3 A Helpful Tool	20
	4.4 Fast Diagramming	20
	4.5 An Example	21

Page

PART TWO: APPLICATIONS
CHAPTER 5 INTRODUCTION 25

5.1 Areas Discussed 25
5.2 Additional Uses 25

CHAPTER 6 SOLID WASTE COLLECTION 27

6.1 Desired Outcomes 27
6.2 Effectiveness Measures 27
6.3 Process Measures 29
6.4 Summary 30

CHAPTER 7 SOLID WASTE DISPOSAL 32

7.1 Desired Outcomes 32
7.2 Effectiveness Measures 32
7.3 Process Measures 34
7.4 Summary 35

CHAPTER 8 WASTE WATER COLLECTION, TREATMENT, AND DISPOSAL 37

8.1 Defining Outcomes 37
8.2 Effectiveness Measures 37
8.3 Process Measures 39
8.4 Summary 40

CHAPTER 9 STREET MAINTENANCE 42

9.1 Desired Outcomes 42
9.2 Effectiveness Measures 42
9.3 Process Measures 48
9.4 Summary 48

CHAPTER 10 TRAFFIC MANAGEMENT 50

10.1 Desired Outcomes 50
10.2 Effectiveness Measures 50
10.3 Process Measures 54
10.4 Summary 54

CHAPTER 11 MASS TRANSIT 56

11.1 Desired Outcomes 56
11.2 Effectiveness Measures 58
11.3 Process Measures 60
11.4 Summary 60

Page

CHAPTER 12 MOTOR-FLEET OPERATIONS 62

12.1 Desired Outcomes 62
12.2 Effectiveness Measures 63
12.3 Process Measures 65
12.4 Summary 67

PART THREE: AN ILLUSTRATION

CHAPTER 13 INTRODUCTION

13.1 Purpose 69

CHAPTER 14 ORGANIZATION. 70

14.1 Setting 70
14.2 Motor Fleet Manager 70
14.3 Maintenance Branch 70
14.4 Operations Branch 72

CHAPTER 15 DATA COLLECTION 73

15.1 Equipment Inventory 73
15.2 Shop Repair Orders 73
15.3 Maintenance Control Log 74
15.4 Equipment History Files 74
15.5 Dispatch Records 74
15.6 Summary 74

CHAPTER 16 REPORTING 77

16.1 Available Equpiment Hours Versus Scheduled Service Delivery Hours 77
16.2 Number of Service Interruption Hours per Scheduled Service Delivery Hours 79
16.3 On-the-Road Breakdowns per 100,000 Miles 79
16.4 Unscheduled Versus Scheduled Repairs 80
16.5 Average Vehicle Downtime 81
16.6 Vehicle Downtime While Awaiting Parts 82
16.7 Vehicle Miles per Quarter (Utilization) 83
16.8 Number of Operator Caused Repair Orders 84
16.9 Number of Repeat Repairs 84

Page

16.10 Number of Motor Pool Requests Denied 85
16.11 Cost Efficiency Measures 85
16.12 Number of Vehicles per Mechanic . . 86
16.13 Number of Repairs per Vehicle . . . 87
16.14 Actual Manhours Versus Standard Manhours 88
16.15 Average Downtime per Repair 88
16.16 Cost per Motor Pool Dispatch . . . 89
16.17 Summary 89

REFERENCES 91

APPENDIX A FAST DIAGRAMING 94

LIST OF TABLES

Table		Page
1	Efficiency Calculation	11
2	Efficiency Index	12
3	Output-Input Data	13
4	Output Weight Factors	13
5	Output Indices	14
6	Input Indices	15
7	Efficiency Index	15

LIST OF FIGURES

Figure		Page
1	System Model for Performance Evaluation . .	6
2	Solid Waste Collection FAST Diagram	23
3	Solid Waste Dispoal FAST Diagram	33
4	Waste Water Collection, Treatment, and Disposal	38
5	Street Maintenance	43
6	Traffic Management	51
7	Mass Transit	57
8.	Motor Fleet Operations	63
9.	Maintenance Control Log Column Headings	75
10.	Relationship Of Manhours Per Repair And Repairs per Vehicle to Maintenance Efficiency	88
A-1	Fast Diagraming Procedures	96
A-2	Revised Solid Waste Collection Fast Diagram	98

LIST OF EXHIBITS

Exhibit		Page
1	Function Worksheet	24
2	Illustrative Performance Report Solid Waste Collection	31
3.	Hypothetical Organization Chart For Motor Fleet Operations	71

MEASURING
PUBLIC WORKS PERFORMANCE

PART ONE

THE PRINCIPLES OF PERFORMANCE MEASUREMENT

CHAPTER 1

INTRODUCTION

1.1 Why Performance Measurement?

This report is concerned with evaluating the performance of local government public works services, programs, and projects, particularly in small and medium-sized cities. Program evaluation in general is a growing area in the field of public administration. This growth can be viewed as part of a larger trend toward the development and adaptation of improved management technology in the public sector. This growth has accelerated in recent years due primarily to the financial difficulties experienced by many governments and the general recognition that government must operate within a framework of more limiting financial constraints than in previous periods. The resulting heightened concern with increasing effectiveness, efficiency, and accountability of government and the delivery of public services has spawned greater interest in program evaluation, along with such managerial techniques as program and zero-based budgeting,

cost accounting, management by objectives, management information systems, and productivity review programs.[1]

There is a clear need for quantitative information on what local governments are doing with the billions they spend, $118 billion in 1972.[2] Local government is the political level most immediate to citizen needs, anxieties, and frustrations and is the one to which citizens turn when worry arises over the quality of education, the growth of crime, the adequacy of transportation facilities, the problems of pollution and the like. Its very nearness makes its activities of even more concern since it remains the one level of government into which a citizen has some potential for direct input and occasionally even the power to say "yes" or "no."

1.2 What Should be Measured

Output from the public sector is not the final product sought by the taxpayer-consumer. Unlike the loaf of bread that is physically ingested, public output involves the "thing" done through collective action to advance toward some desired end state, often vaguely specified, such as security, cleanliness, ease of access, heightened intellectual capacity, or better health. Citizens and taxpayers are concerned with how these "outputs" become transformed into the "outcomes" they desire.[3]

For some services outputs can approximate objective, physical units that are directly measurable, such as miles

of streets paved or tons of garbage collected. Many measures of service outcomes, however, are statistical artifacts, such as units of prevented crime, which are not immediately observable but are derived by fairly complex statistical operations.[4] Furthermore, most services have, instead of a single dimension of final output, a number of dimensions that must be combined before the service output can be appropriately defined.

CHAPTER 2

ELEMENTS OF PERFORMANCE EVALUATION

2.1 Traditional Approaches

Any systematic procedure for evaluating the performance of a public program will necessarily involve specifying criteria on which the evaluation is to be made and then measuring actual program performance on the basis of these criteria. The problem with much of what still passes as "evaluation" in local government is that it deals solely with the "front-end" of service delivery--inputs such as expenditure amounts, staff size and qualifications, or the facilities and materials available--or focuses on the service delivery process itself, including such characteristics as types and extent of various activities conducted, techniques used, and workload measures.[5] While these are certainly important aspects of program design and operation, examination of these factors alone cannot provide an indication of overall program performance. True performance evaluation, however, should center on the end products of the program, its results or what it really accomplishes.

Program evaluation requires a thorough familiarity with the program's objectives, operating design, and environment.

The first problem in program evaluation depends on an understanding of the program's objectives and the design of the program as it is intended to lead to their accomplishment, along with the environmental factors which might influence a program's success or failure. With ongoing programs, officials often drift into a state of great concern with routine activities and internal operating efficiency while losing sight of what a program should be all about. A systems approach to program evaluation is a valuable tool.

2.2 A Systems Perspective

Systems analysis for this purpose can be defined as the analysis of a program as a set of interacting elements aimed at achieving some common overall objective(s).[6] A principal feature of systems analysis is the important distinction between those factors which are under control of program management and those which are beyond its control.

2.2.1 Environmental Factors

Many factors which influence program performance are external to the program itself and cannot be manipulated by program management. Environmental variables characterize the operating context of the program. They can be of a physical, socioeconomic, attitudinal, legal, financial, or institutional nature, can act either as constraints or opportunities and can be present in both external and

internal organization environments. Figure 1 depicts a systems model of program variables.

2.2.2 Inputs

Inputs are the things--usually manpower, money, and facilities--which are available for use in a program. Traditional program evaluations have been keyed to an assessment of the quality and quantity of inputs, rather than to real performance evaluation. This is largely because inputs are generally the easiest data to obtain and are the most visible in the budgeting process. Such evaluations do not test whether the program actually works.

2.2.3 Program Operation Variables

Program operation variables are the systems, techniques, and decision processes used by service managers in converting inputs into the products desired. It is the area most under control of government administrators and reflects their judgment in system design.

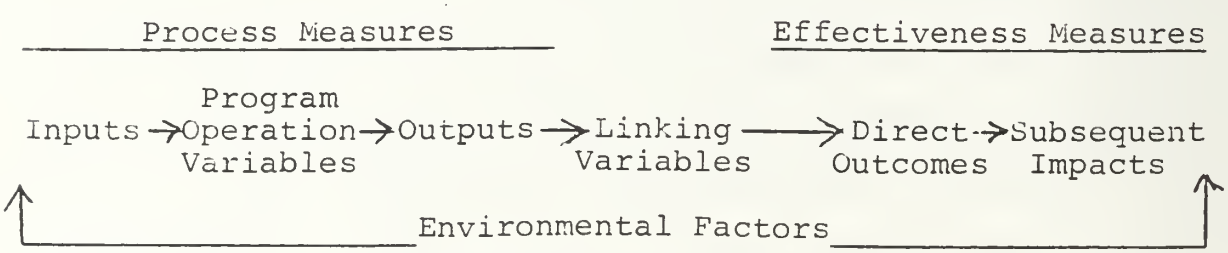


Figure 1. Systems Model for Performance Evaluation.[7]

2.2.4 Outputs

The most direct products of a program are outputs, which can be thought of as units of programmed activity. Outputs have no inherent value in and of themselves, but they are an important link in the underlying program logic, which holds that the production of outputs will trigger the occurrence of the desired effects or impacts in the environment. Outputs tend to be measures of workload or work completed, such as tons of refuse collected or miles of streets cleaned. In evaluation of program effectiveness, we are concerned with outputs in two respects: (1) are outputs being produced as planned, and more important, (2) are these outputs leading to the desired outcomes?

2.2.5 Linking Variables

Outputs are intended to drive direct outcomes on the environment. Cause-effect logic often describes the linking variable between outputs and outcomes. Encouraging owners to upgrade property to community standards may be the intended direct impact of a city's building code enforcement office. Evaluating this office merely on the output basis of the number of citations issued is inadequate. Evaluating the change in the number of noncompliant structures over a period of time may be a more appropriate yardstick of performance effectiveness.

2.2.6 Outcomes

Direct outcomes too may lead to other subsequent environmental impacts. Efforts to bring buildings up to certain standards may be part of a broader program to upgrade city or neighborhood appearance, which in turn may be a subcomponent of a city or county drive to attract new business or economic activity to a community.

True performance evaluation then should be comprised of two distinct but related criteria, process efficiency and program effectiveness.

CHAPTER 3

PROCESS MEASURES

3.1 Productivity Indicators

Colloquial use of the term productivity traditionally focuses on process measures. Process outputs, measured by final products or services produced, are divided by inputs, measured by labor hours, staff years, or resource costs, to provide a productivity indicator. Calculating this index over a period of time informs managers of trends, changes, and feedback on the effectiveness of implemented improvement initiatives. The term is also synonymous with efficiency measurements.

3.2 Outputs

Output measures must apply to the most representative product or service produced to ensure that the measures developed give an accurate reading of the level of efficiency. They should indicate the information managers need to evaluate progress toward achieving goals. One output measure may be appropriate for an organization which has only one major mission. In most cases, however, some breakdown of outputs will be necessary either due to multiplicity of organizational mission or the presence of interim steps in

the production process. The following tests for defining output may be helpful in establishing process measures.

- Mutually exclusive. Can the input required to produce the output item be readily identified?
- Process definable. Are the same steps required to complete the operation each time?
- Countable. Can the number produced be identified?
- Uniform over time. Will the nature of the product remain relatively stable over a reasonable period of time?
- Mission oriented. Does the item represent all or a significant part of the mission of the activity being measured?
- Quality definable. Item quality becomes a problem only when it changes, but definition of it is needed to determine if change has occurred. If changes have occurred these can usually be factored in to adjust the productivity equation.
- Data readily available. To what extent are data available from existing systems?
- Directness of measure. Are the measures direct? or, if indirect measures are necessary, is there a rational relationship between the output and the measure?[8]

3.3 Inputs

Labor is the simplest and most commonly used input measure.[9] It is most appropriate where labor comprises a major portion of the operating costs or where the proportion of labor to other costs remains relatively constant. Caution is required in overvaluing efficiency improvement through capital expenditures. Converting trash collection from curbside pick-up of household containers to centrally located dumpsters would reflect significant labor productivity improvement; however, the increased capital expenditure

for dumpsters and handling equipment may result in a net reduction in cost per unit of solid waste collected. Special analysis and development of total or multifactor measures of the historical relationship between labor and total costs can identify this type pitfall.

3.4 Efficiency Indexing

Upon determining the appropriate output and input criteria, efficiency can be derived through simple division. [Efficiency = Output ÷ Input]. Table 1 illustrates this calculation for a theoretical refuse collection operation. An embellishment on this approach, which can be more meaningful for time lapse comparison purposes is computation of an efficiency index.[10] This index shows how efficiency has increased or decreased with respect to the base period.

Table 1

Efficiency Calculation

Year	Output (tons collected)	Input (man years)	Efficiency
1	20	5	4 tons/man years
2	30	6	5 tons/man years
3	40	7	5.7 tons/man years

An output index for year 2 is computed by dividing 30 tons (year 2) by 20 tons (base year 1) and multiplying times 100. An input index is computed in the same manner (see Table 2). The efficiency index then reflects the percent change in efficiency from the base year.

3.5 Complex Indices

When an organization produces more than one output, each with differing labor intensities, efficiency indices for the organization are more difficult to compute. In this case outputs are weighed by the labor required to produce one unit of output in the base year. Table 3 displays raw data for a hypothetical street maintenance department.

Output weights are determined by dividing the first years' (or base year) inputs by the first years' outputs as in Table 4. The output quantities each subsequent year are

Table 2

Efficiency Index

Year	Output Index	Input Index	Efficiency Index
1	100	100	100
2	150	120	125
3	200	140	143

Table 3

Output-Input Data

Outputs	Output Quantity	Input (Man years)
Year 1		
(1) Pothole repair (Sq. Yd.)	5,000	25
(2) Resurfacing (Sq. Yd).	100,000	20
(3) Road Inspector (lane miles)	200,000	5
Year 2		
(1) Pothole repair (Sq. Yd.)	6,000	30
(2) Resurfacing (Sq. Yd.)	75,000	20
(3) Road Inspection (lane miles)	250,000	5
Year 3		
(1) Pothole repair (Sq. Yd.)	6,000	25
(2) Resurfacing (Sq. Yd.)	150,000	15
(3) Road Inspection (lane miles)	175,000	5

Table 4

Output Weight Factors

Output	Year 1 Output	Year 2 Input	Output Weight factor
(1) Pothole repair	5,000	25	25/5,000=.005
(2) Resurfacing	100,000	20	20/100,000=.0002
(3) Road Inspection	200,000	5	5/200,000=.000025

multiplied by the output weight factor. Weighted outputs are then indexed against the base year. Table 5 illustrates.

Input Indices are computed in the manner previously discussed using total man years (See Table 6).

The efficiency indices for the department can now be determined as illustrated in Table 7.

Table 5

Output Indices

Output	Output Quantity	Output Weight Factor	Weighted Output	Output Index
Year 1				
(1) Pothole Repair	5,000	.005	25	
(2) Resurfacing	100,000	.0002	20	
(3) Road Inspection	200,000	.000025	5	
			50	50/50=100
Year 2				
(1) Pothole repair	6,000	.005	30	
(2) Resurfacing	75,000	.0002	15	
(3) Road Inspection	250,000	.000025	6.25	
			51.25	102.5
Year 3				
(1) Pothole Repair	6,000	.005	30	
(2) Resurfacing	150,000	.0002	30	
(3) Road Inspection	175,000	.000025	4.38	
			64.38	128.8

Table 6

Input Indices

Year	Input Man Years	Input Index
1	50	100
2	55	110
3	45	90

Table 7

Efficiency Index

Year	Output Index	Input Index	Efficiency Index
1	100.0	100	100.0
2	102.5	110	93.2
3	128.8	90	143.1

3.6 Multifactor Measurement

Total or multifactor indices require consideration of other inputs such as capital, interest, depreciation, materials, overhead/support burdens, supplies, full rents and so forth. These inputs are readily expressed in monetary terms to provide a common denominator. Costs are adjusted to base year indices through either (1) multiplying current costs by a deflator such as the wholesale price index, inflation statistics etc. or by (2) multiplying current year unit inputs times the base year unit prices. It is important to use total factor input when labor is only a small portion of total costs or when the mix of the various inputs is changing. In general it can be said that:

- When efficiency is declining, the total factor decline is not as great as the decline using labor only and conversely.
- When efficiency is rising, total factor efficiency normally rises more slowly than labor efficiency only.[11]

3.7 Pitfalls

While efficiency indexing provides a simple means of monitoring process performance several stumbling blocks are inherent in the methodology. First, the efficiency index is valid only where the quality of the product or service remains constant. Raising or lowering service quality requires adjustment of base year inputs to reflect provision of equivalent service. Failure to do so would result in erroneous efficiency changes.

Outputs which are too general in nature will result in inaccurate indices when the mix of services changes. In the previous example of the street maintenance department, repairing potholes is 200 times more labor intensive as road inspection. (.005 ÷ .000025 = 200). Had outputs not been detailed sufficiently and weighted, the efficiency index for the department would fluctuate disproportionally with changes in output composition.

CHAPTER 4

EFFECTIVENESS MEASURES

4.1 Meeting Objectives

Program effectiveness is measured in terms of meeting objectives.[12] In measuring program effectiveness we are concerned with whether immediate objectives are being accomplished and, if so, whether they are leading to the attainment of intermediate and ultimate objectives. Typically, effectiveness measures, especially measures of subsequent impact, are the most difficult to develop good indicators for--certainly they are the most important.

The criteria for evaluating the effectiveness of public programs stem directly from their objectives.[13] Thus they relate to the intended changes or benefits in the environment which the program is expected to produce. Effectiveness criteria should be observable, measurable conditions, and if possible, they should set standards against which actual accomplishments can be measured. When objectives have been clearly specified with respect to magnitude of effects and time frame, such standards are already given. When statement of objectives are not specific, evaluators have two options: (1) try to determine what level of performance could reasonably be expected and set standards

accordingly, or (2) use open-ended questions and proceed without clear cut criteria. This second approach is appropriate when the purpose of the evaluation is to measure the extent to which a program is producing the intended impacts and suggest ways of improving performance.

4.2 Specifying Outcomes

As illustrated in Figure 1 effectiveness measures evaluate the success of prescribed outputs to generate desired outcomes. Simply stated, outputs from the service production process become inputs for program or community goal accomplishment. Government process outputs are intended to favorably impact on a community's environment. Program objectives may be focused to provide specific service to a targeted population i.e. low income housing or as general as ensuring the health and safety of the populace at large. Effectiveness measures establish how well goals are met.

Effectiveness cannot always be quantified to express results numerically as is the case with efficiency issues. For example, effectiveness in preventing vehicle accidents/ damage by promptly repairing potholes is difficult, if not impossible, to determine. This is because vehicle accidents are influenced by many factors outside the control of the governmental department repairing pot holes.

Effectiveness is obviously a principal concern of the manager. Doing the right things, providing efficient,

responsive, high quality services is counterproductive when done for the wrong reasons, when they do not advance the achievement of community valued goals.

4.3 A Helpful Tool

When commencing a new service or when the original intent of an existing program has become obscured with time the linkages between process outputs and program objectives can become very nebulous. One technique for clarifying these issues, borrowed from value engineering, is Function Analysis System Technique (FAST) diagramming.[14]

FAST diagramming when used in value engineering is a tool to identify the functions a product, product component, or system under review provides and shows their relationship to other functions. It also helps check for missing functions and aids in identifying the scope or limits of area under study. Its use in evaluating municipal service delivery is to aid in identifying the linkages between service delivery process outputs and the program or community outcomes they are supposed to affect. Identifying desired outcomes leads directly to determining effectiveness measures.

4.4 Fast Diagramming

The first step in this process is to list service outputs or products. A form borrowed from value engineering, the function worksheet, can be used for this process: See

Exhibit 1. In the left hand column of the form answers to the question, why is this product, service, or function performed?, are recorded. In the right hand column methods used to accomplish the services, the how, are recorded. Answering these questions provides insight into the conceptual linkages between processes, outputs, and outcomes.

The second step in the procedure is to display the relationships between processes outputs and outcomes in diagram form. High order functions, the desired outcomes, appear to the far left on the diagram and their relationship to outputs and processes appear to the right.

4.5 An Example

To illustrate, consider the solid waste collection function of local governments. Answers to the why question include (1) prevent health hazards, (2) enhance community appearance, and (3) to prevent indiscriminate dumping. All these functions relate to the higher order governmental function to provide for public health and safety. How refuse is collected varies from one jurisdiction to another but generally (1) equipment is procured, (2) labor is hired, (3) service is provided, and (4) revenues are collected to pay for the service. The FAST diagram displaying the relationships of these functions appears as Figure 2.

The value engineering purist will note that broad liberties have been taken in the application of FAST

diagramming techniques to this study. Only basic concepts are used here to assist in identifying service delivery effectiveness measures. Parker's Value Engineering Theory[14] provides more information. Appendix A displays more stringent FAST diagramming methodology as it applies to this topic.

FUNCTIONAL PHASE

STUDY

FUNCTION WORKSHEET

WHY?	FUNCTION	HOW?

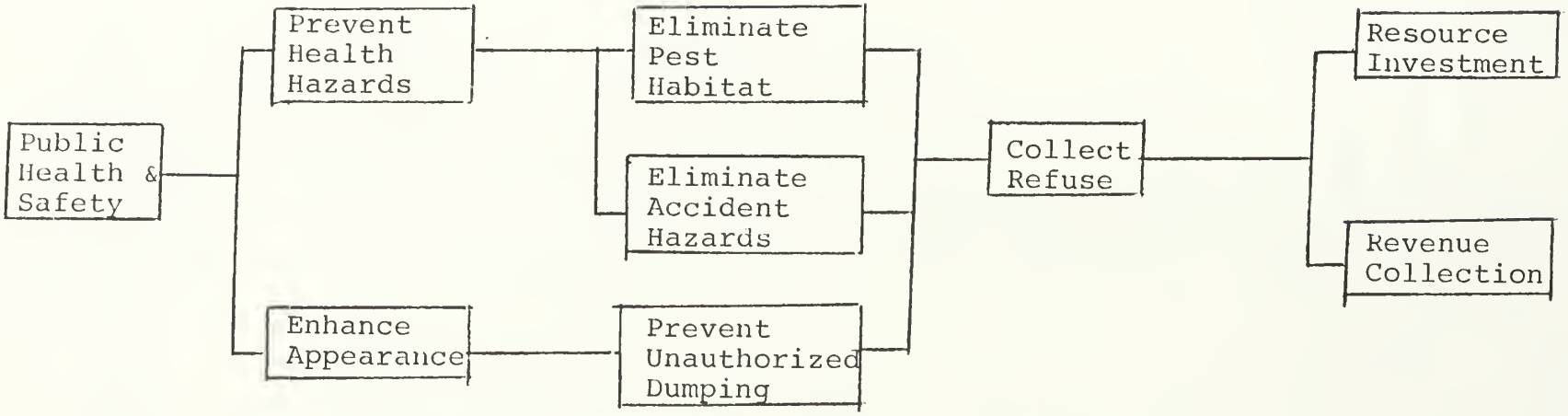


Figure 2. Solid Waste Collection FAST Diagram

PART TWO
APPLICATIONS

CHAPTER 5

INTRODUCTION

5.1 Areas Discussed

The principles of performance measurement developed in Part One, FAST diagramming, process measures, and effectiveness measures, are theory until applied to actual programs. This section of the report will demonstrate these ideas as they may be applied to public works services including solid waste collection and disposal, waste water collection, treatment, and disposal, street maintenance, traffic management, mass transit, and motor fleet operations.

5.2 Additional Uses

The evaluation criteria developed provide a starting point for local jurisdictions to embark on systematic appraisal of service delivery. They should be tailored to fit the peculiar requirements and capabilities of each service delivery operation. Establishing acceptable performance levels is also a matter for local jurisdictions based on capabilities, fund limitations, and their established goals.

Once established and data gathering procedures have been affected performance measurement assumes many beneficial notes. In addition to monitoring performance it can be used in conjunction with the budget process to determine required and/or desired funding levels. Performance measures can form the basis for preparing service delivery contract documents and evaluating contract versus force account performances decisions. Finally, if standardized they can provide the framework for intra-jurisdictional comparison of governmental effectiveness.

CHAPTER 6

SOLID WASTE COLLECTION

6.1 Desired Outcomes

Refuse collection services are provided by most cities through force account employees, private contractors or intergovernmental agreement. Americans spent more than 2 billion dollars in 1974[15] to remove the roughly 100 million tons of refuse generated at home.[16] In order to evaluate the effectiveness of this service it is first important to ask why cities collect refuse in the first place. Application of FAST diagramming to this question results in Figure 2.

This diagram is over simplified in that refuse collection is not the only means of eliminating pest habitats nor is refuse collection the only element required to provide for public health and safety. What is depicted are the major reasons for a city's collection of solid waste and the relationship of this to a major governmental function.

6.2 Effectiveness Measures

Suggestions for appropriate effectiveness measures are suggested by the diagram. One effectiveness measure is the effectiveness of refuse collection in preventing illness and

accidents. Measuring provention of anything is difficult if not impossible to establish since there are no events to document. A proxy measurement would be to document the number of illness and accident cases directly related to uncollected refuse. This statistic can be related as a number of incidents per 1000 people, per collection dollar cost, or per 1000 households served. When documented periodically, trends over time would indicate service improvements, deterioration, and problem areas.

Systematic inspection of street cleanliness, using predetermined indexes, have been employed by some cities.[17] Criteria are documented with written descriptions and color photographs and are used to rate area and overall cleanliness. These data are used to determine the effectiveness of the collection system and can be expressed in terms of index points per collection dollar cost, per household, or per 1000 households.

Another effectiveness measure can be obtained through citizen satisfaction surveys.[18] Respondents are asked to rate their satisfaction with existing service and identify their major complaints. Changes in the percent satisfied over time reflect changes in service effectiveness and citizen comments can help managers identify areas requiring improvement. Citizen surveys have the added advantage of leveraging administrators and legislators into budget expenditures to improve collection effectiveness.

Citizen complaints are a low-cost, convenient and useful measure of effectiveness.[19] The number and type of documented valid complaints per period, per household, 1000 households, pick-up, 100 pick-ups, or cost, when recorded over time can yield insight into the effectiveness of service delivery.

6.3 Process Measures

Efficiency measurement is simpler in concept but the data collection requirements may be equally as difficult to ascertain as that for effectiveness indicators. Cubic yards of refuse collected is an unsatisfactory output measurement due to the difficulty of estimating volumes of individual containers and the compaction characteristics of various collection vehicles. Truckloads of refuse collected is affected by the carrying capacities of individual trucks. Tons of garbage is much more accurate and is not subject to operating system vagaries and is the most highly recommended output measure.[20]

Another output measure pertinent to evaluating process efficiency is the number of households served (occupied dwelling unit). It can be used to supplement tons collected where generation rates or population density vary.

Inputs can be measured by either the labor hours expended or the total cost of operation. Operation costs should include not only burdened labor rates and vehicle operating and maintenance expense but also capital

depreciation and overhead expense to reflect total costs of providing the service.

Using these output/input measures four meaningful process efficiency measures can be calculated.

- Cost per ton collected
- Cost per household
- Tons collected per labor hour
- Households served per labor hour.

6.4 Summary

A theoretical service performance evaluation report is depicted in Exhibit 2.

Exhibit 2

Illustrative Performance Report
Solid Waste Collection

	1982	1983	% Change
Data			
Tons Collected	90,000	100,000	+11%
Households Served	50,000	55,000	+10%
Cleanliness Rating (on scale from 1 to 4)	2.5	2.5	0
Labor Hours	1,500	1,500	0
Costs	1,200,000	1,500,000	+25%
Costs (1982 dollars)	1,200,000	1,350,000	+10%
Complaints Received	2,000	3,000	+50%
Refuse related Health/ Safety Incidents	50	55	+10%
Effectiveness Measures			
Health/Safety Enhancement (incidents/1000 households)	1/1000	1/100	0
Street Cleanliness	2.5	2.5	0
% Citizen Satisfaction (from survey)	85%	80%	- 5%
Complaints per 100 households per year	.04	.06	+50%
Efficiency Measures			
Tons collected per labor hour	60	67	+11%
Households served per labor hour	33	37	+12%
Cost per ton (83 dollars)	$13	$13.50	+ 4%
Cost per household (83 dollars)	$24	$24.54	+ 2%

CHAPTER 7

SOLID WASTE DISPOSAL

7.1 Desired Outcomes

Developing general performance criteria for solid waste disposal is a difficult task in that disposal methods vary from simple landfilling to capital and operating cost intensive thermal processing techniques.[21] Some methods reduce net costs by generating revenue from recycled materials or energy recovery. The decision on which method to use can be driven by many variables including a suitable market for recovered material or energy, relative availability of land, environmental regulations affecting disposal methods, and haul distance between collection and disposal sights. Turning to the FAST diagramming tool some insight to relevant effectiveness measurement criteria may be obtained.

7.2 Effectiveness Measures

Many similarities exist between Figures 2 & 3. Some of the effectiveness measures are also the same. The number of health related incidents related to disposal operations per unit volume or weight of refuse handled would be a proxy measure of illness/accident prevention. Citizen surveys of

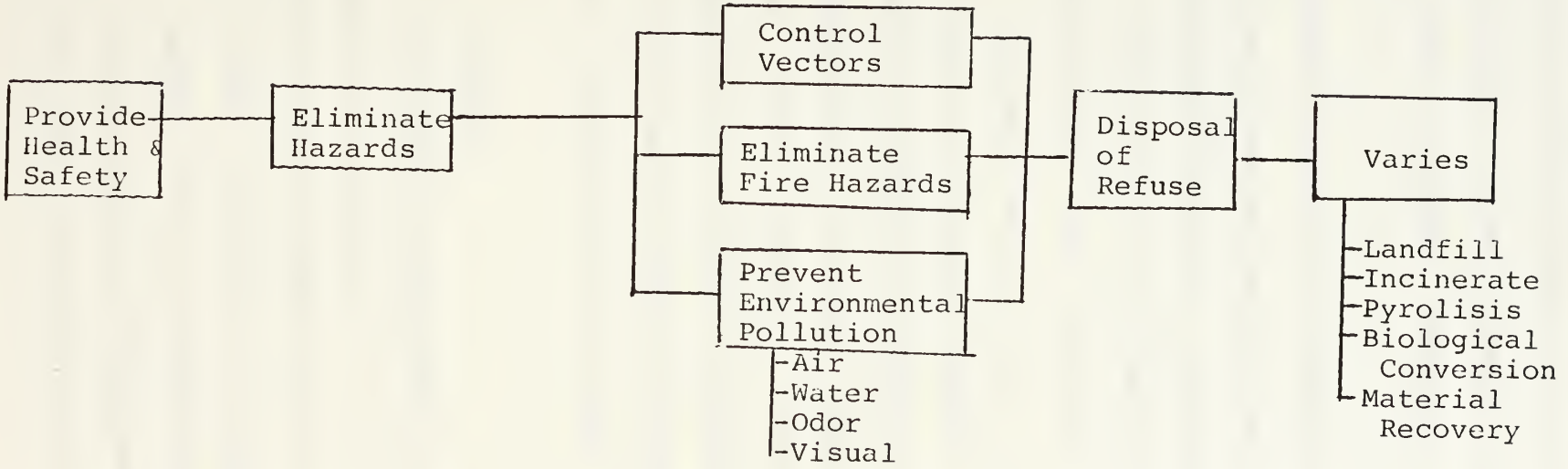


Figure 3. Solid Waste Disposal FAST Diagram

disatisfaction might not be an effective measure due to the minimal expcsure interface between service customers and providers, however, the number of valid complaints received regarding the disposal operation remains a valid measure of effective operation.

Additional performance/effectiveness measures result from the potentially deleterious effects disposal operations might have on the environment. Disposal operation contribution to pollution can be monitored periodically. Leachate contamination would be important at a landfill site, whereas air pollution monitoring would be more important at an incineration or other thermal processsing plant. Standards for air and water quality are set forth in the Resource Conversion and Recovery Act of 1976. In all operations, control of "visual" pollution--loose, blowing debris--would be an essential effectiveness measure. Here again a system of inspection rated against predetermined standards would provide indication of operation performance.

7.3 Process Measures

The denominator for both effectiveness and efficiency measures should be tons (or cubic yards) of throughput through the disposal facility since the process does not yield a measurable output.[22] Throughput would also be the same as weight of refuse coming into the process.

Solid waste disposal differs from most other local government services in that it is very capital intensive.

Labor efficiency is thus less critical than cost efficiency.[23] In calculating the cost of operations, the input side of the efficiency equation, the annualized cost of land, buildings, equipment, vehicles, pollution control devices, etc. should be included with operating costs attributable to labor, fuels, maintenance, insurance, as well as depreciation and overhead. Where appropriate, the "salvage value" of the site should be included in the calculations if it can be converted to another use after reaching capacity.

Output of the process is merely tons processed per period in the case of ordinary landfill operations. Operations employing energy or material reclamation would have additional outputs. Tons of waste recovered as energy or materials, percentage or tonage reduction in refuse requiring landfilling, and monetary revenue generated by sale of energy or recovered material are among the most important efficiency measures to be used.

7.4 Summary

Performance measurements for solid waste disposal are recapitulated below.

Effectiveness Measures

number of illness/accidents reported per ton throughput

number of valid complaints per ton throughput

leachate quality compared to standards

air quality compared to standards

cleanliness rating.

Efficiency Measures

operating cost per ton throughput

total capitalized cost per ton throughput

percent material recovery per ton throughput

percent residual going to landfill

revenue per ton throughput.

CHAPTER 8

WASTE WATER COLLECTION, TREATMENT, AND DISPOSAL

8.1 Defining Outcomes

Performance measures for waste water collection treatment and disposal can be derived from examination of Figure 4.

8.2 Effectiveness Measures

The first effectiveness measure, relating to meeting EPA regulations, would be to track the number of households using environmentally unacceptable waste water removal systems (e.g., septic tanks in saturated land areas) in the service area. An initial survey of unsewered buildings would be required to establish these data but the figures could be updated based on building permit and construction data thenceforth.

Comparative analysis of water quality above and below the discharge outflow point would provide a measure of the impact treatment operations have on the environment. While regulatory standards do not cover this area the Federal Water Pollution Control Act of 1972 and the Clear Water Act of 1977 require elimination of pollutants into the nations water by 1985.[24] Collection and analysis of water quality

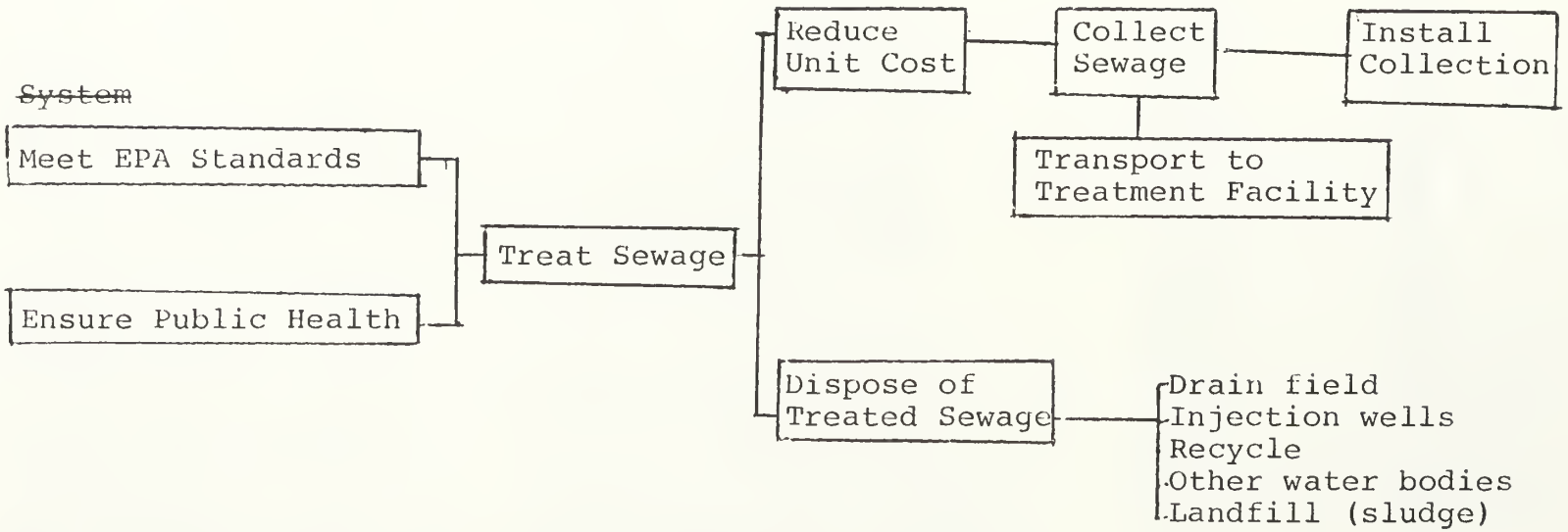


Figure 4. Waste Water Collection, Treatment, and Disposal

data, both up and downstream from the discharge point could justify or refute the desirability of this goal.

Another effectiveness measure would be comparison of effluent quality to regulatory standards. Fecal coliform, BOD (percentage removed and concentration), pH, phosphates, nitrates, and oil and grease can all be measured and compared to federal standards. The number of days per period--week, month, year--that standards are not met can also be recorded and used as an effectiveness measure.

Additional effectiveness measures for the collection system are required. Monitoring system infiltration and exfiltration measures not only effectiveness but also indicates the collection system's condition. Eliminating infiltration can greatly affect treatment facility capacity requirements.

The number of collection system interruptions per mile of pipe is another measure of collection system effectiveness. These data would be easily collected from maintenance records.

The number of waste water system complaints per thousand households served and citizen satisfaction levels, obtained through surveys are also appropriate effectiveness measures.

8.3 Process Measures

Inputs for efficiency measurement for waste water collection, treatment, and disposal, like those for refuse

disposal, are capital intensive. Annualized land, building, equipment, and sewer line costs should be included to obtain total system costs. Annual operating and maintenance expenses should include total costs including labor salaries and fringe benefits, energy costs, supplies, and overhead. The value of effluent recycled for irrigation, recreation, and industrial or domestic use should also be credited to operating cost.

Using volume of water treated as the system output, efficiency measures become total cost, operation and maintenance (O & M) cost, and labor cost or hours per thousand gallons of sewage. Again, efficiency measures can be segregated to specifically cover collection. O & M cost per mile of pipe orlabor hours or cost per mile reflect operating efficiency.

8.4 Summary

Following is a summary of effectiveness and efficiency measures for waste water collection, treatment, and disposal systems.

Effectiveness measures:

number of households with unacceptable treatment water quality upstream versus downstream from treatment facility

effluent quality verses EPA standards.

- BOD
- fecal coliform

- acidity
- phosphates
- nitrates

number of days per month quality levels not maintained

percent of sewage treated as a function of water supplied (after accounting for losses can indicate infiltration or exfiltration in collection system)

number of service interruptions per mile of pipe

number of valid complaints per thousand households

customer satisfaction levels.

Efficiency measures:

total cost per thousand gallons collected/treated

O & M cost per thousand gallons collected/treated

labor cost per thousand gallons collected/treated

repair cost per mile of pipe.

CHAPTER 9

STREET MAINTENANCE

9.1 Desired Outcomes

Street maintenance and traffic management functions are closely related and may in fact be performed within the same municipal department in some cities depending on the size and complexity of the jurisdiction. Both are complicated functions having several individual subfunctions. Street maintenance is addressed here and traffic management in a separate subsequent section to simplify presentation. Where both functions are performed in the same department these sections should be combined to evaluate overall performance.

Street maintenance is another function where what is done is well documented but the reasons for doing it may have been obscured through time. FAST diagraming provides insight into this dilemma and aids in identifying appropriate effectiveness measures. (See Figure 5).

9.2 Effectiveness Measures

Many effectiveness measures are apparent. Some are easier to evaluate than others. Maintenance effectiveness in preserving the capital investment in pavement structures is possibly most difficult to evaluate. At best only proxy

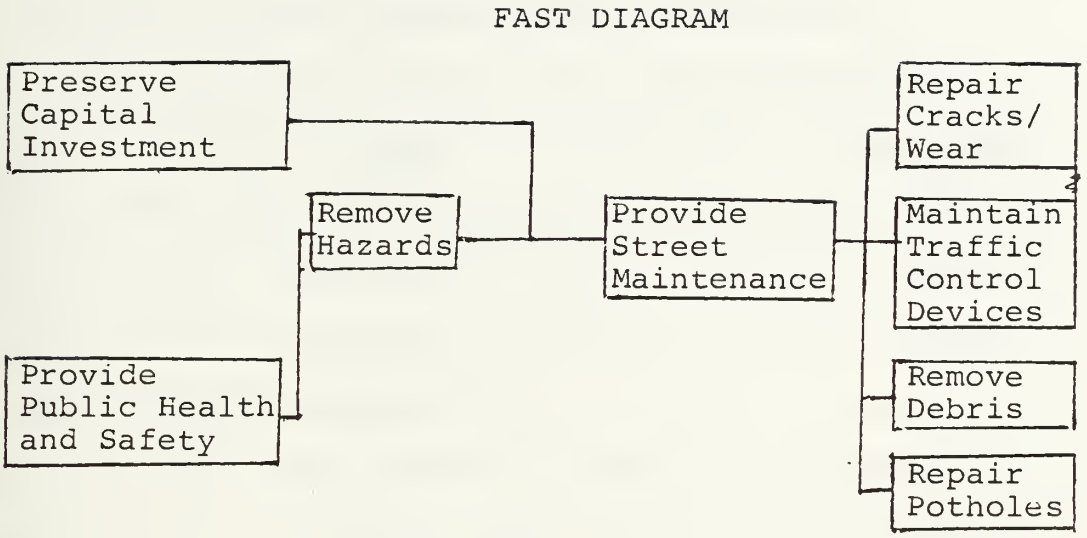


Figure 5. Street Maintenance.

measures may be developed. One criteria would be a comparison of actual structure service life to designed service life. Early pavement replacement could indicate poor maintenance. There are many problems with this approach because ineffective maintenance practices are not the only factors affecting pavement serviceability. Poor original design or changed traffic conditions can have at least as great an effect on structure life as does maintenance.

Another option would be to determine the average remaining service life of existing pavements. This would be accomplished by inspection and weighted averaging of remaining service life as illustrated in Table 6.

While this measure doesn't relate directly to maintenance effectiveness, changes in the average life from year to

Table 6

Determining Average Remaining Service Life

Remaining Life	Lane Miles	Service Index
1 year	30,000	30,000
3 years	50,000	150,000
5 years	100,000	500,000
10 years	75,000	750,000
15 years	60,000	900,000
20 years	40,000	800,000
30 years	10,000	300,000
TOTAL	365,000	3,430,000

$$\text{Average Service Life} = \frac{3{,}430{,}000 \text{ lane mile years}}{365{,}000 \text{ lane miles}} =$$

$$= 9.4 \text{ years}$$

year will indicate the effectiveness of the maintenance program in achieving predetermined improvement goals. Declining average age could reveal poor maintenance program performance. The single factor beyond manager control which can have the greatest effect on average age is program funding level. With adequate funding, average age would

rise to an equilibrium level where program costs balanced or equaled community benefits of well maintained streets--another factors which could cause drastic fluctuation in community growth or annexation. This indicator has the added advantage of forecasting, and to some extent justifying, future capital budget requirements when repair costs are multiplied by lane miles requiring extensive repair in each future year.

A third alternative for measuring maintenance effectiveness would be to compare process output against statistically derived required activity levels to ensure prolonged serviceability for each maintenance activity. For example, if there are 5,000 miles of expansion joints in a city's concrete-paved streets and joint sealant has an expected life of 5 years, then an effective maintenance program would replace 1,000 miles of joint sealant per year. Actual program output, if adequately funded, compared to this required activity level, would yield a program effectiveness measure. Similar activity levels and effectiveness measures would be developed for other maintenance functions such as pothole repair, lane markings, resurfacing and so forth to derive an overall program effectiveness measure. This approach is somewhat arbitrary yet could serve to be a proxy measure of program effectiveness in preserving the community's capital investment in transportation facilities.

Yet another preservation effectiveness measure associated with street maintenance would be derived by

monitoring the maintenance and repair backlog. Maintenance backlog would be determined through annual condition inspections. Yearly required activity levels, in terms of backlog reduction or specific project accomplishment, would be determined during the budgeting process. Comparison of actual performance to this activity level would yield a proxy effectiveness measure.

The second category of effectiveness measure for street maintenance relates to removal of safety hazards. An obvious measure would be monitoring of the number, severity, and rate of traffic accidents attributable to poor street maintenance. Again, accidents rates are a proxy measure for the number of accidents prevented. The utility of this measure is limited. Most fatal accidents are reported as are a majority of nonfatal personal injury cases.[25] The reporting of property damage accidents varies greatly depending on legal requirements, police department practices, and public attitudes.[26] Since many accidents relating to street maintenance would result in property damage, vehicle wheel misalignments from hitting potholes and so forth, many accidents may not be reported. Other measures may be more meaningful.

One alternate measure would be the number of traffic hazards removed. In the case of potholes this could be measured by the number repaired or the cubic yards of patching material used. Both measures used in conjunction with one another would be most beneficial since the volume

of material used per repair would provide an indication of the severity of the condition corrected.

Another measure of accident hazard elimination would be the number or backlog of repair requests based on inspection results or valid citizen complaints. Closely related to this measure is the response time of maintenance crews to elimination of reported hazards. Care must be taken to ensure that initial response for hazard avoidance, erecting barriers, flashers, detour routing and so forth, is recorded separately from hazard removal, final elimination of the hazardous condition and restoration of conditions, if there is significant time elapsed between the two events. Examples of maintenance requirements, other than potholes, where these measures are important is signage, signalization, street marking, and street lighting when these functions are the responsibility of the street maintenance department.

Street cleaning is the final aspect of maintenance requiring effectiveness measures. This is an area which is highly subjective. What is adequately clean for one person may not be so for another. One approach is to establish cleanliness standards, based on verbal description and pictures, and use these standards to rate cleanliness on a scale of 1 to 10 (or any other predetermined scale). Effectiveness would then be established through periodic inspection and comparison to this standard.

9.3 Process Measures

Efficiency measures for street maintenance are a bit easier to develop. Labor efficiency can provide relevant measures in this area as labor costs account for 40 to 90 percent of the general budget.[27] Total cost efficiency could be used occasionally to verify gains made in labor efficiency. Output measures include pounds of joint sealant applied, lane feet slurry seal applied, shoulders reshaped, streets swept, pavement marking applied, cubic yards of patching material used, and so forth. In addition to measuring actual performance over time performance can be compared to estimated requirements or predetermined labor standards.

9.4 Summary

Summarized street maintenance effectiveness and efficiency standards include

Effective measures

- average remaining service life of pavements
- process output versus required activity level
- maintenance and repair backlog
- accident rate attributable to street maintenance activities
- number of traffic hazards removed
- response time for hazard elimination
- cleanliness rating

Efficiency measures

cost per repair activity

number of repairs by type per man hour

repair rate versus maintenance standard.

CHAPTER 10

TRAFFIC MANAGEMENT

10.1 Desired Outcomes

The traffic management function relates to the planning, design, operation, and management of transportation networks within a city or other governmental jurisdiction.[28] This function may be a part of the street maintenance department or may be part of the public works or city engineer's office. In large jurisdictions it may be an independent department.[29] A FAST diagram for this function appears below in Figure 6.

10.2 Effectiveness Measures

As can be seen, traffic management effectiveness can be measured in terms of traffic flow, the total number of vehicles moving through a corridor, and the number of accidents that occur. Traffic flow measures, to be meaningful, are related to individual roadways or corridors. Accidents can be counted per intersection or for an entire jurisdiction. The measures commonly used in evaluating system performance are:

traffic flow

capacity

operating speed

travel time

delays

accident prevention

traffic conflicts

erratic maneuvers and near misses

accidents.[30]

Street capacity is usually expressed in terms of vehicles per lane per hour average daily traffic (ADT).[31] Capacity calculations are important in the design of roadways but can be used in effectiveness measurement only

FAST Diagram

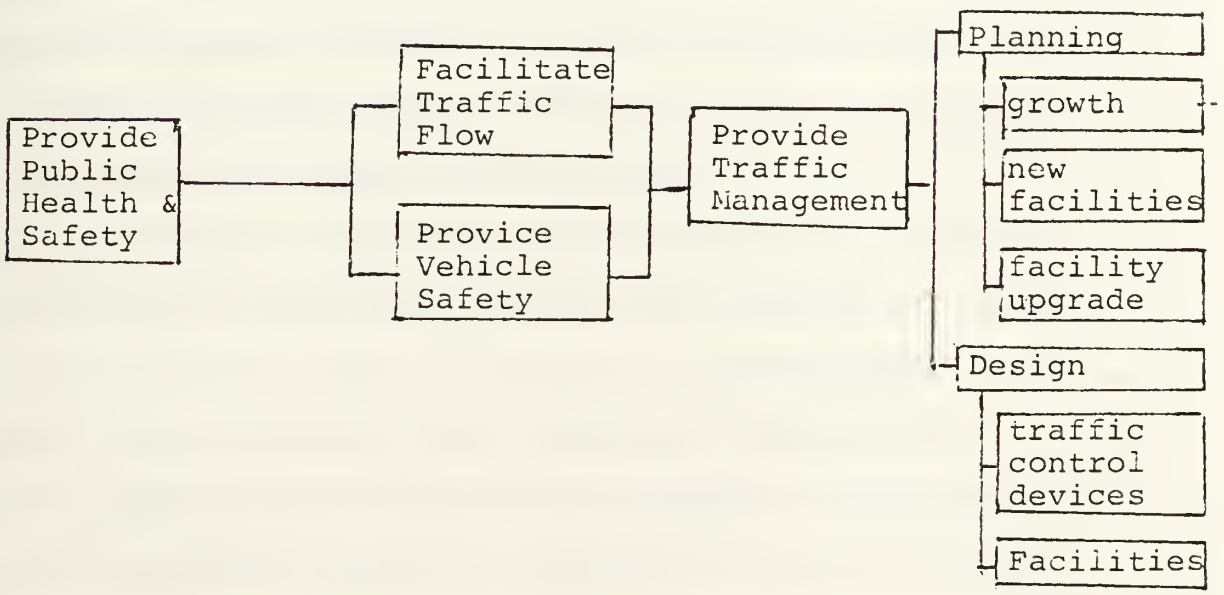


Figure 6. Traffic Management.

when actual traffic volumes approach or exceed design capacity. Here they can provide an evaluation tool to judge the effectiveness of various corrective options to increase capacity to meet existing or projected future traffic demands.

Operating speed is the highest vehicular speed on a given highway under favorable conditions and prevailing traffic conditions and limits.[32] It is important for effectiveness measurement because of its relationship to capacity and traffic flow. Increased operating speeds with maximum capacity means increased effectiveness.

Delays are measured by time lost while traffic is slowed or halted at traffic signals, traffic jams, detours, and similar impediments to traffic flow. Reduced delays, measured in seconds per vehicle, represent increased effectiveness.[33]

Travel time is the average time it takes to travel from one place to another under prevailing roadway and traffic conditions. It is perhaps the most important traffic flow effectiveness measure as it represents the cumulative effects of operating speed and delays. Travel time when coupled with corridor capacity adequately defines traffic flow effectiveness.

The functions of speed, flow stability, and traffic volume are interrelated as an effectiveness measure known as operational level of service. Service levels are rated from A (the best) to F (the worst) in the Highway Capacity

Manual.[34] At the service level where maximum capacities are obtained with stable and reasonable flow, maximum effectiveness exists. This level is usually associated with level of service C (satisfactory) or D (poor), in which the capital resource invested to achieve this level of operation yields a high cost/benefit ratio and a high degree of traffic flow effectiveness.[35]

Traffic conflicts, evasive maneuvers, and near misses along with actual accident experience are measures of vehicle safety effectiveness. Near misses are much more numerous than accidents but because they are difficult to record are really not useful as an effectiveness measure.

Traffic conflicts and erratic maneuvers are closely related and include sudden lane changes, turns from the wrong lane, abrupt stops in traffic, and backing against traffic. Traffic conflicts relate to highway safety, particularly at intersections.[36] Erratic maneuvers and traffic conflicts are predictors of traffic troubles and are easily observed and tabulated. Reductions in their incidence are evidence of increased effectiveness.

Accident statistics are meaningful effectiveness measures in that there are existing systems for recording and tabulating them. Accidents can be expressed in rates per vehicle entering spot locations (intersections) or per vehicle-mile for sections and highways. Accidents can be broken down further into categories of fatal, nonfatal personal injury, and property damage only accidents. The

U.S. Department of Transportation and the National Safety Council publish estimated economic loss per accident for these categories annually.[37] Using these figures in conjunction with accident rates can aid identification of dangerous traffic conditions and indicate vehicle safety effectiveness.

10.3 Process Measures

Labor efficiency is an appropriate measure for traffic management efficiency since management input is primarily engineering or clerical. System outputs include designs, studies, and improvements in transportation system effectiveness.

Efficiency measures include cost per project developed or problem resolved. The average time it takes to complete assignments, or response times, also provide an indication of efficiency. Changes in system effectiveness expressed in dollars saved by accident reduction or increases in traffic flows can be used in efficiency indices of cost per dollar saved. A final efficiency index, although of limited usefulness except for comparing efficiency between similar jurisdictions, is the management input per system lane mile.

10.4 Summary

Traffic management performance measures are summarized below.

Effectiveness measures

travel time between destinations

travel time from city center to city limits

average Highway Capacity Manual Service level

erratic maneuvers and traffic conflicts per 1000 vehicles

accidents per 100,000 vehicle miles (total and fatal, personal injury, and property damage)

Efficiency measures

projects completed per staff person

project cost developed per staff hour cost

savings from accident reduction per cost to develop

savings from traffic flow increases per cost to develop

lane miles serviced per staff person or cost.

CHAPTER 11

MASS TRANSIT

11.1 Desired Outcomes

Mass transit is part of the total transportation requirement that includes highways, the automobile, traffic engineering, pollution control, the environment, and energy conservation.[38] Bus service, light rail, heavy rail, and paratransit are alternative means of providing mass transit. Organizing these objectives and means in logical sequence for identifying appropriate effectiveness and efficiency measures is assisted through use of the FAST diagramming tool (see Figure 7).

Unexpected linkages encountered in Figure 7 is the split between providing mass transit for people with and without automobiles. While many functions immediately to the left of the "move people" category could apply equally well to both, there are much stronger linkages as diagrammed. People without cars, or one car per household with more than one working member, require transportation to and from employment centers as well as to other essential social services such as medical facilities, recreation facilities, shopping facilities and so forth. Their primary

FAST Diagram

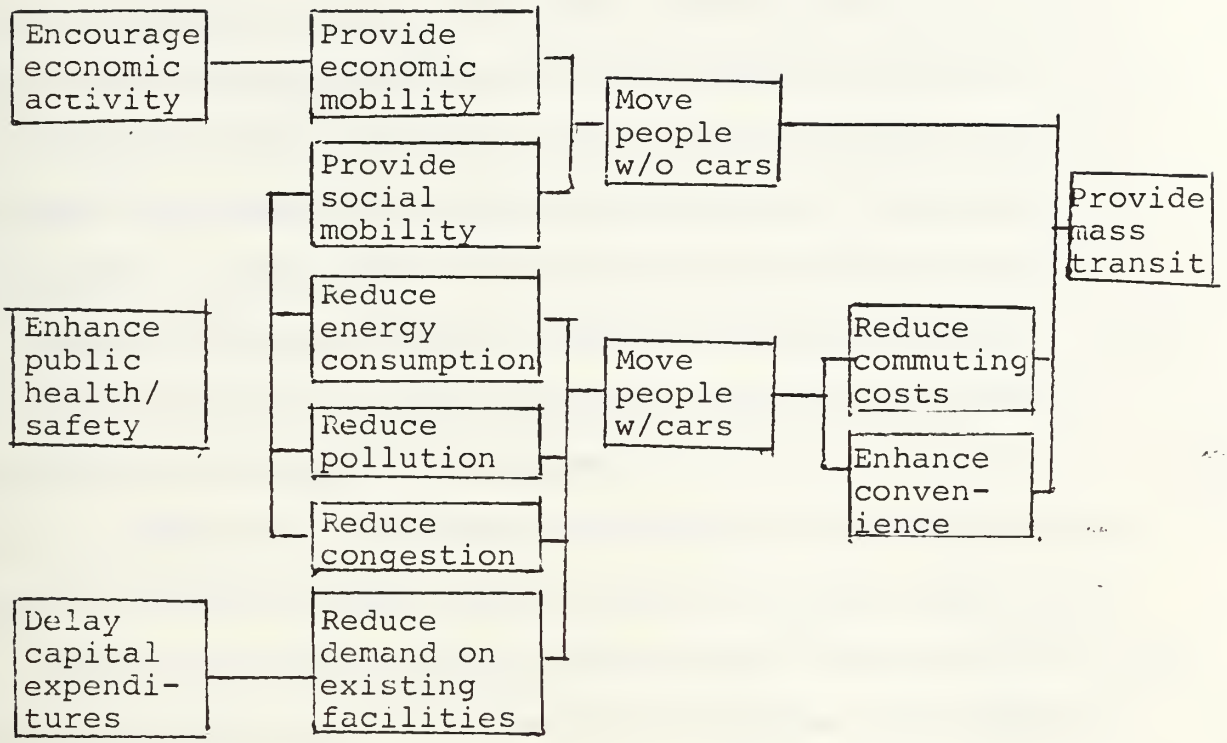


Figure 7. Mass Transit.

motivations for using mass transit do not include conserving energy, reducing pollution, or reducing traffic congestion. These functions as well as delaying capital expenditures for increasing traffic carrying capacity of existing transportation facilities are more reasonably described as concerns for local governments. To achieve these objectives government must induce people with automobiles into higher density modes of transportation, including mass transit. Incentives for accomplishing this, beyond appealing to asethetic sensitivity for the environment or energy conservation, include reducing individual commuting costs while maintaining or enhancing user convenience.

11.2 Effectiveness Measures

One measure of effectiveness is to determine the system's accomplishment in serving population and destination centers. Population center analysis should include statistics on automobile density and income per household as well as population density and demographics. Destination centers include employment centers, schools, parks, churches, shopping, medical facilities and so forth. Based on these data transit system effectiveness can be expressed in terms of the percent of total or target population served, and the average walking distance between origin or final destinations and the nearest embarkation point. Statistics would also be available for expressing the percent of population and destination centers served.

Transit system effectiveness at reducing energy consumption, air pollution, and traffic congestion would be difficult to monitor for communities experiencing either growth or decline. In communities with stable population and economic activity improvements in these areas could be affected by a transit system. However, external changes in automobile efficiency, composition of automobile fuel usage (diesel versus gasoline engines), and even weather can have at least as great effect as an effective mass transit system.

A more suitable measure, although a proxy measure, would be to record the number of trips per day taken on the mass transit system. Better still, if data are available,

would be expressing mass transit trips as a percentage of all commuter trips. These data need not be system wide. Percent of mass transit trips to major destination centers would provide an indication of effectiveness. The effectiveness linkage to system objectives is that increasing ridership consistent with or above the community growth rate will achieve reduced per capital energy consumption, pollution, congestion, and demand for transportation system capital improvement requirements.

Enhancing commuter convenience as used here includes reliability, travel time, and service frequency. Reliability can be measured in two ways, 1) percent of scheduled runs actually completed, and 2) deviation from scheduled arrival times. Both can be measured for the total system or by route to pinpoint problem areas.

Travel time should be expressed in minutes per average door to door trip. This figure, when compared to the time required to make the same trip by automobile, provides an indication of how desirable mass transit might be to potential new customers. It is not probable that mass transit will be as fast as automobile transportation except under special circumstances--express route on reserved lanes for example. It would be possible, however, to derive the ratio where mass transit becomes a viable alternative. A commuter may be willing to ride a bus where the trip takes one and a half times as long as an automobile trip but not when the trip takes three times as long. Once a reasonable

ratio has been established it can be used as an effectiveness measure for other routes and the overall system.

Service frequency relates to headway between buses on a given route. It is an important effectiveness measure as it relates to convenience and also in comparing routes within a system or comparing one transit system to another. The implication of service frequency is that a route with shorter headways would be more convenient, and therefore more effective than one with a longer period between buses.

A final effectiveness measure can be derived from surveys of system users and nonusers. Survey questions should be geared toward determining perceptions of service adequacy and satisfaction. Satisfaction levels provide an indication of effectiveness and citizen criticism can identify measures for improving performance.

11.3 Process Measures

Efficiency measure inputs can include labor, vehicles, and maintenance statistics as well as total system cost and revenue generation. System outputs include vehicle miles, passenger miles, trips, or hours of operation.

11.4 Summary

Appropriate efficiency ratios using these data and the effectiveness measures described above include:

Effectiveness measures

percent destination center served

percent population served

walking distance to bus stop

percent of commuter trips taken on mass transit

average travel time

travel time versus automobile travel time

service frequency

surveys of satisfaction

Efficiency measures

maintenance cost per vehicle or operating hour

operating cost per bus mile or operating hour

passenger revenue per bus mile or operating hour

revenue per employee

revenue/cost relationship per route

energy cost per passenger mile

percent of inoperable buses

revenue miles per bus

average bus miles between road calls

ratio of scheduled versus unscheduled maintenance requirements.

CHAPTER 12

MOTOR-FLEET OPERATIONS

12.1 Desired Outcomes

Local governments depend on a wide variety of motorized equipment to deliver services to citizens. Equipment types range from police vehicles, fire apparatus, buses, refuse trucks, and weight handling equipment to pumps, air compressors, welding machines, and lawn mowers. Operation, maintenance, replacement, and other capital costs rank second only to personnel as a resource in determining the operating budget of service agencies.[39] Appropriate performance measurements of this function are essential to effective management. The measures developed here are appropriate for use in a centrally managed operation. Additional measures may be required where motor fleet management is performed by separate service agencies.

The FAST diagram for motor-fleet operation, Figure 8, is straightforward. The major objective of this function is to ensure that all motor equipment necessary for service delivery is available when needed. Implied in this objective is that the vehicles will also be reliable and cost effective.

FAST Diagram

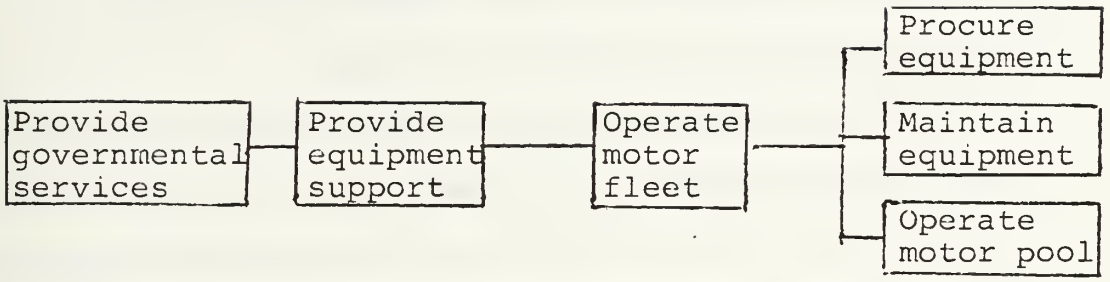


Figure 8. Motor Fleet Operation.

12.2 Effectiveness Measures

The number of available equipment of each type of equipment compared to the number of hours needed for service delivery is one indication of system effectiveness. Excess available equipment hours could indicate excess equipment if service delivery demand is constant throughout the year.

For motor pool operations the number of unfilled requests for equipment also provides an availability effectiveness measure. Care must be exercised in using this index to ensure appropriate demand scheduling and workload leveling procedures are utilized. Excessive unscheduled demands at peak times could result in a high unfilled request rate while there may actually be too many vehicles during a majority of available operating hours.

While available equipment hours may meet demand there still may be service interruptions due to equipment failures while in use. The ratio of the number of hours of service interruption to hours of planned service delivery provides a

third effectiveness measure. Equipment reliability is measured in conjunction with road service repair time and the availability of reserve equipment.

An effectiveness measure more closely related to reliability alone is the number of on-the-road breakdowns per 100,000 miles (or 1000 hours) of equipment operation. Excessive road maintenance calls reflects poor equipment reliability effectiveness. Outside factors which can adversely affect this reliability measure are inadequate maintenance and operator error or abuse.

Several measures of maintenance effectiveness are appropriate. One measure is the number or ratio of repeat repairs per total repair work orders completed. Excessive repeat repairs reflects poor maintenance effectiveness.

Poor maintenance effectiveness will also be revealed by comparing the number of unscheduled equipment breakdown repair orders to the number of scheduled preventive maintenance repair orders. Effective preventive maintenance performance will result in a low ratio.

The other side of the equipment availability coin is equipment downtime. Excessive downtime, expressed as a percent of on hand equipment or equipment hours per period (usually weekly) reflects ineffective operation even though available hours meet service demand. Reduced downtime in such a case would allow elimination of excessive vehicles and their associated capital cost.

Total downtime can be broken down into component factors to provide additional effectiveness measures. Parts availability, repair priorities, and actual repair time are components of total downtime. Calculating downtime in these categories can highlight problem areas and measure effectiveness improvements.

Vehicle utilization rates provide additional insight into motor-fleet operation effectiveness. This factor, expressed in terms of miles or hours operated per quarter, can highlight individual vehicle assignments which fall significantly below fleet averages as candidates for reassignment, return to the motor pool, or disposal as excess equipment.

Operator maintenance was identified above as a factor which can adversely affect reliability effectiveness measures. Operator maintenance requirements generally include checking vehicle fluid levels, tire pressures, and operability of lights, windshield washers, turn signals, brakes and so forth on a daily basis. Monitoring breakdowns caused by operator failure to perform these requirements or repairs caused by operator neglect and abuse (including accident repair) provides an additional essential effectiveness measure.

12.3 Process Measures

Motor-fleet operation efficiency relies on capital, labor, materials, fuel, and where appropriate contracting

costs. Vehicle availability is system output. Total cost input includes vehicle replacement and service interruption costs as well as normal operation and maintenance and insurance costs. An overall efficiency measure for this function is the total cost per hour of equipment utilization. Alternately, total cost per vehicle mile or hour is also an overall efficiency index. Useful information can also be derived by calculating similar ratios for each category of equipment--sedans, dump trucks, cranes, and so forth.

Maintenance efficiency can be expressed in many ways. Maintenance cost per vehicle per year is one measure. Another is maintenance cost per mile or hour of operation or per hour of availability.

Maintenance efficiency can also be expressed in terms of mechanic labor input. The number of vehicles maintained per man year reflects efficiency and can be used to determine staffing levels. Average man hours per repair order readily reflects efficiency improvements. Another, and possibly better, labor efficiency measure is the ratio of actual maintenance labor as a percent of standard (flat rate) maintenance labor.

The number of repairs per vehicle per year provides another efficiency measure. The average down time per repair order (shop turnaround time) is also an important efficiency measure.

Motor pool operating efficiency can be expressed in terms of the cost per vehicle dispatch or cost per vehicle in the pool.

12.4 Summary

Motor fleet operation effectiveness and efficiency measures are summarized below.

Effectiveness measures

- available equipment hours versus scheduled service delivery hours.
- number of motor pool requests denied
- number of service interruption hours per scheduled service delivery hour
- on-the-road breakdowns per 100,000 miles
- number of repeat repairs
- unscheduled versus scheduled repair orders
- average vehicle downtime
- vehicle downtime while awaiting parts
- vehicle miles per quarter (utilization)
- number of operator caused repair orders

Efficiency measures

- cost per utilized vehicle hour
- cost per vehicle mile
- maintenance cost per vehicle
- maintenance cost per mile
- number of vehicles per mechanic
- man hours per repair order

actual man hours per standard man hour

number of repairs per vehicle

average downtime per repair

cost per motor pool dispatch

cost per motor pool vehicle.

PART THREE
AN ILLUSTRATION

CHAPTER 13

INTRODUCTION

13.1 Purpose

Parts One and Two presented the theoretical background and illustrated the applications of performance measurement for several public works functions. The final section of this report demonstrates application of these principles to a hypothetical operating department. Motor fleet operations was selected as this area affects many other service delivery systems. Organization relationships, data sources, and analysis responsibilities will be outlined to derive the performance measures developed in Chapter 12.

CHAPTER 14

ORGANIZATION

14.1 Setting

Exhibit 3 displays the motor fleet operations function as it might appear in a typical city organization. The involvement of the city's elected officials, manager and staff, and other operating departments in performance evaluation will be discussed later. The motor fleet operation division is discussed below.

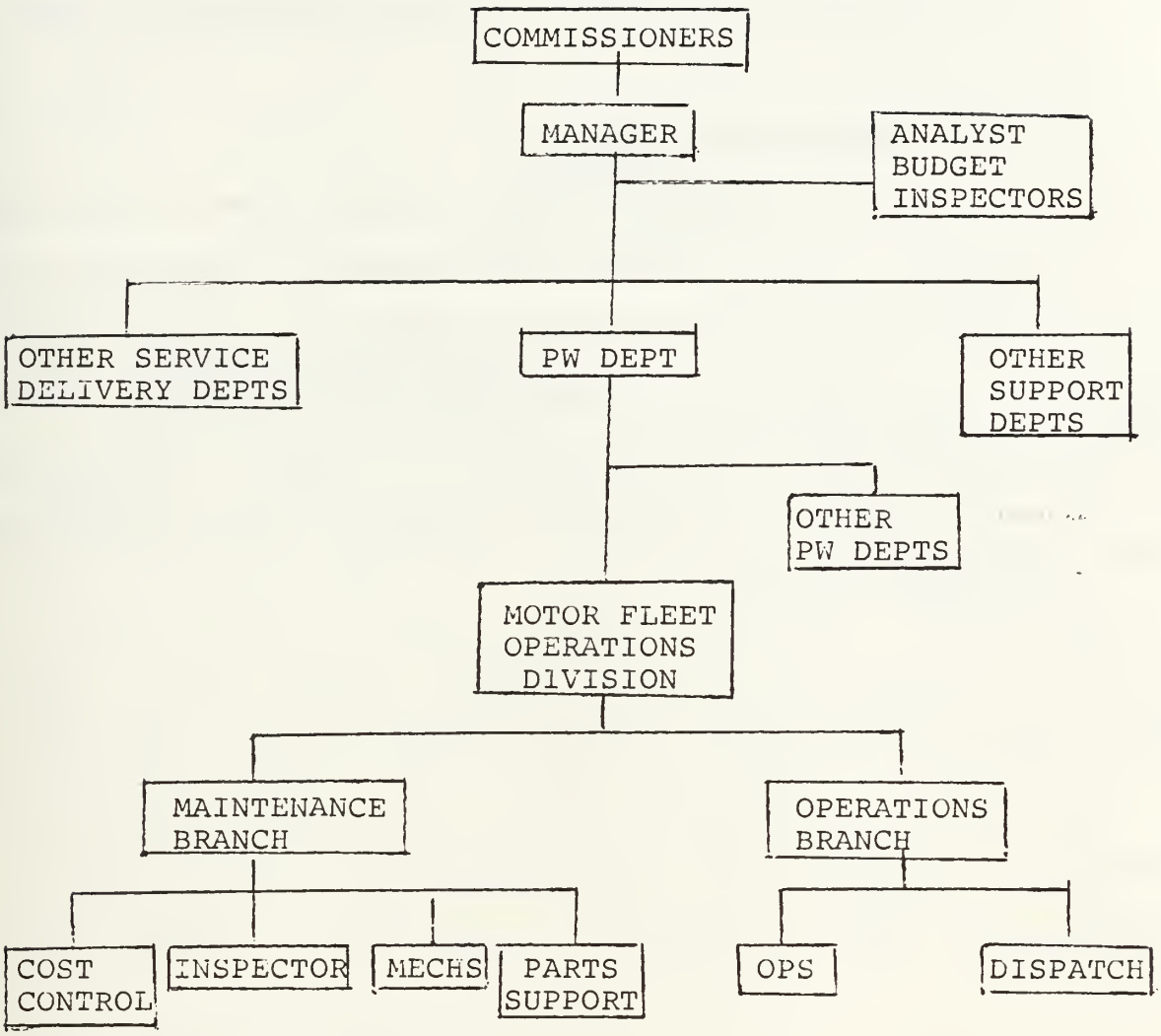
14.2 Motor Fleet Manager

The motor fleet manager is responsible for day to day operation of the division. He manages the division's budget, personnel, and capital assets, and ensures required reports are completed as scheduled.

14.3 Maintenance Branch

The division is divided into two branches. The maintenance branch performs all equipment repair functions and records and files maintenance data on each piece of equipment. The branch is comprised of vehicle inspectors, mechanics, and record clerks. The parts support function,

EXHIBIT 3



HYPOTHETICAL ORGANIZATION CHART FOR MOTOR FLEET OPERATIONS

while an integral component of maintenance, is often under the management control of a central purchasing office.

14.4 Operations Branch

Equipment dispatching is accomplished by the operations branch. Heavy equipment operations for specialized construction equipment--cranes, bulldozers and the like--would also be a part of the operations branch if this type support is required by other operating divisions. Ensuring motor pool equipment is ready for issue is also a responsibility of this branch.

CHAPTER 15

DATA COLLECTION

15.1 Equipment Inventory

An accurate inventory of all equipment under the fleet manager's control is a fundamental prerequisite for data collection and reporting. Each piece of equipment must have a separate identification number. Grouping equipment by type, buses, sedans, pumps, trucks, and so forth, is also an important step to ensure operation and maintenance histories of like equipment can be fairly compared. The inventory document should also reflect where the equipment is assigned and odometer or hour meter reading at the time of inventory.

15.2 Shop Repair Orders

Standard shop repair orders (SRO's) eases documenting repair actions, material use, maintenance histories, and labor efficiency. Standard forms are available for this use. An appropriate SRO will provide for recording the vehicle identification number, equipment type and year of manufacture, current vehicle odometer reading, date equipment enters and leaves the shop, repair description, estimated and actual repair times, and space for recording type, quantity, and cost of parts used.

15.3 Maintenance Control Log

Figure 9 displays column headings recommended for a maintenance control log book. As can be seen columns are provided to track vehicles from the time they enter the maintenance process until returned to service.

15.4 Equipment History Files

Each piece of equipment should have its own maintenance history file. This file should contain pertinent equipment specifications, preventive maintenance requirements and all completed shop repair orders for maintenance work performed on it. A maintenance history log in the front of the file, where SRO numbers, dates, downtime, labor hours, and material costs can be recorded as repairs are made, would speed periodic review of individual equipment performance.

15.5 Dispatch Records

Motor pool issues should be made using vehicle trip "tickets" upon which is recorded the vehicle identification number, date and time of issue and return, beginning and ending odometer readings, and the destination and number of stops made while the vehicle is in use.

15.6 Summary

These basic documents, the inventory and assignment record, the maintenance control log book, shop repair orders, the equipment history file, and vehicle dispatch

SRO Number (1)	Vehicle Identification Number (2)	Date Input (3)	PM ? (4)	Road Call ? (5)	Date Work Started (6)	Date Parts Ordered (7)

Date Parts Received (8)	Date Work Restarts (9)	Date Work Completed (10)	Estimated Labor Hours (11)	Actual Labor Hours (12)	Work Downtime (7)-(6)+(10)-(9) (13)

Parts Downtime (8)-(7) (14)	Total Downtime (10)-(3) (15)

Figure 9. Maintenance Control Log Column Headings

trip tickets, comprise the bulk of data source information for all the reports required for the performance measures discussed in Chapter 12. Chapter 16 describes the procedures used to calculate those effectiveness and efficiency measures and suggests potential use, analysis, and decisions that could be made as a result of them.

CHAPTER 16

REPORTING

16.1 Available Equipment Hours versus Scheduled Service Delivery Hours Report

Available equipment hours are derived by subtracting equipment downtime from the total possible hours of equipment availability. If the period under discussion is a week the calculation would be as follows.

$$A = (B \times C) - D$$

where

A = available equipment hours

B = the number of pieces of equipment in inventory

C = the number of days (or hours) in the reporting period

D = the total equipment downtime in days (or hours) for the reporting period.

Total equipment downtime is computed by summing column (15) of the maintenance control log book for vehicles entering the shop during the reporting period.

Scheduled service delivery hours must be obtained from the city departments which require use of equipment. Inputs

should be made at the beginning of the reporting period based on the anticipated or budgeted activity levels for the coming period. Using "E" to represent scheduled service delivery hours this effectiveness measure, "F", is expressed as:

$$F = A/E$$

A number greater than one should be expected. If this ratio is less than one service delivery functions are not being met. This could be caused by 1) overstatement of requirements, 2) excessive equipment downtime, or 3) not enough equipment in the inventory. A ratio very much greater than one would indicate either an understatement of requirements or excessive equipment in inventory. This ratio should ideally range from 1.0 to 1.1. Results falling outside this range should initiate indepth analysis by the city manager and/or his staff to uncover the source of the problem. Should altering service delivery levels or changes in inventory be required the city commission would make appropriate budgeting decisions.

This effectiveness measure could be further refined by calculating it for each organizational unit using equipment. Doing so would indicate which delivery organizations deviated significantly from the norm and speed analysis.

16.2 Number of Service Interruption Hours per Scheduled Service Delivery Hour

This effectiveness measure allows evaluation of the severity of service interruptions. Data may be collected by the maintenance record clerk in conjunction with the motor pool dispatcher who would be involved in issuing a back-up vehicle if available. A more reliable procedure, which eliminates potential errors due to communication difficulties, would be for adversely affected service delivery organizations to record and report service interruptions to either the public works director or city manager for consolidation with input other departments.

Acceptable performance levels must be established by each individual jurisdiction. Ideally there should be no unscheduled service interruptions. A more reasonable objective might be one to five percent. Service interruption levels can be affected by 1) breakdown frequency, 2) breakdown severity, 3) responsiveness of road service crews, 4) operator errors or neglect, 5) preventive maintenance, and 6) the availability of reserve equipment. Poor performance regarding service interruption should prompt investigation of these factors by the city manager's staff, the public works director, and most particularly the fleet manager.

16.3 On-the-Road Breakdowns per 100,000 Miles

Closely related to service interruption hours is the frequency of on-the-road breakdowns. Used in conjunction

they provide insight into the number and severity of breakdowns which in turn indicates the general maintenance condition of the fleet.

On-the-road breakdowns are determined from summing column (5) of the maintenance control log. Mileage is determined as discussed below under equipment utilization.

Acceptable performance levels can vary dramatically with the relative age of the equipment. A fleet comprised of relatively new equipment will have a much lower breakdown rate than an aging fleet. Acceptable levels must be determined by the city's elected officials who make the purse-string decisions to replace, perform major overhaul, or let the condition continue. Cost-benefit analysis in this area is possible if breakdown costs, idle crew time, undelivered services, towing, and so forth, as a result of service interruption are estimated. The true value of this effectiveness measure is knowing what current performance levels are and evaluation of the impact management decisions have on changing it.

16.4 Unscheduled versus Scheduled Repairs

This ratio is determined by dividing the number of non-preventive maintenance (PM) shop repair orders, from the maintenance control log, by the number of PM repair orders. This ratio reflects the effectiveness of the PM system but can be affected by fleet condition.

This ratio should ideally be less than one. The author has seen ratios as high as seven or eight breakdowns per PM. Aggressive pursuit of improving the PM program effectively reduced this rate. Again manager's (and city council) knowledge of current performance levels and the result of corrective actions are invaluable to effective performance.

16.5 Average Vehicle Downtime

Total vehicle downtime is determined from the maintenance control log. This figure is divided by the total possible available equipment time described above in paragraph 1.1. Downtime should normally range from five to ten percent. Higher percentages reflect ineffective maintenance workload management or parts support. Lower percentages could indicate excess equipment inventory. Care must be taken, however, to take into consideration vehicle age as this also will have some effect on maintenance requirements and parts availability.

Vehicle downtime can be computed weekly or monthly for use by the fleet manager and public works director to help keep close tab on day to day maintenance management. Less frequent reports, perhaps quarterly, should be provided to the city manager to keep him appraised of performance trends. Elected officials may or may not desire periodic reports but would be interested in this performance measure, along with the other effectiveness indices, during the budgeting process.

16.6 Vehicle Downtime While Awaiting Parts

Downtime attributable to unavailability of repair parts is obtained by summing the column (14) of the maintenance control log. Several denominators provide valuable insight into the affect parts support has on maintenance performance. It can be divided by total downtime to determine its proportion of that figure. It can be divided by the number of shop repair orders which experience parts delay to reflect average response time. Dividing the number of SRO's which do not experience parts delay by the total number of SRO's provides an indication of whether the parts department is adequately stocked.

Response time of parts procurement is an important factor in downtime. It generally will vary with the proximity of local parts dealerships or distributors. Response time averages under two days (16 downtime hours) should not be uncommon, especially in large jurisdictions where suppliers are numerous. Averages in excess of five days (40 downtime hours) per SRO probably reflect deficiencies. Acceptable parts department stock levels should be established with response time in mind. Where response time is one or two days, a parts room which meets 80% of the SRO requirements may be acceptable. If long lead times cannot be overcome, 95% demand satisfaction may be desired even though this would mean more capital would be required for parts inventory. Both these factors affect the contribution of parts delay to total downtime. A balance

which contributes less than ten percent of total downtime would reflect effective parts support.

These measures should be computed and reported at least as frequently as downtime is calculated. This will alert functional manager and the city administrator to adjust to developing trends.

16.7 Vehicle Miles per Quarter (Utilization)

Vehicle utilization should be determined quarterly. Odometer readings of each vehicle can be determined in several ways. Perhaps the most accurate method would be physical data gathering. Significant manpower could be expended in this effort and there are other, though less accurate procedures. Odometer readings recorded on the shop repair order when the vehicle was last in the shop could be used. Vehicle users could read odometers and forward this input to the fleet manager. More sophisticated systems could utilize odometer readings obtained when the vehicle was last fueled.

Upon determining vehicle mileage during the period utilization by individual departments can be evaluated. Vehicles showing low utilization (mileage) become candidates for reassignment, return to the motor pool, or disposition.

This effectiveness measure can be used by the city manager in evaluating whether service delivery departments have accurately stated requirements, determine relative merit of one assignment versus another, and provide insight

into the adequacy of fleet inventory levels in meeting demand.

16.8 Number of Operator Caused Repair Orders

This effectiveness measured should be documented and reported by the maintenance inspector. He sees and inspects every vehicle entering the shop for repair and is best qualified to determine if operator behavior has resulted in undue repair requirements. Examples of these problems include repairs caused by failure to perform operator maintenance checks, coolant and oil levels and so forth, equipment over loading, and accidents. Monthly or, at a minimum, quarterly reports should be provided the public works director and city manager for analysis and corrective action. Severe cases of operator abuse should be reported immediately to the service delivery department supervision by the fleet manager or public works director.

16.9 Number of Repeat Repairs

These data could be documented by the inspector as vehicles enter the shop for repair. Perusal of the vehicles' maintenance history file would readily reveal whether the equipment failure had occurred previously and is attributable to improper mechanic performance. Should the public works director or city manager suspect the data or desire independent verification a staff analyst could sample

equipment history files on a periodic, perhaps yearly, basis.

Repeat repairs should be kept to a minimum. When unacceptable performance is observed in-depth review of the inspector's records should pinpoint errant mechanics and corrective measures can be taken.

16.10 Number of Motor Pool Requests Denied

The motor pool dispatcher is in the best position to gather these data. A simple log book could be utilized. As stated in Chapter 12 care must be taken to ensure only valid denials are included. Demands met by vehicle type substitutions, rescheduling, or trip consolidations reflect effective motor pool operation even though the request is not filled as desired by the equipment user.

This information should be reviewed on a quarterly basis to guide the fleet manager in recommending and the city manager and council in evaluating changes in vehicle inventory.

16.11 Cost Efficiency Measures

Cost of vehicle maintenance and operation is normally available from municipal budget and expenditure documents. The level of detail available on capital costs, fuel expenses, overhead expense, and other total cost factors depends on the sophistication of the accounting system. All

readily available costs commensurate with ease of collection should be used in calculating cost efficiency measures.

Utilized vehicle hours and miles were derived previously. Simple division provides the efficiency indices. One or more of the cost efficiency measures presented in Chapter 12 should be computed at least on an annual basis.

The cost per utilized vehicle hour or mile can be used in budgeting service delivery functions and for cost-benefit analysis of new equipment investment. Changes in this measure, adjusted for inflation, also reflects the success of management decisions geared toward improving efficiency. These measures can also be used as a yardstick by the fleet manager in identifying individual pieces of equipment whose costs greatly exceed norms.

16.12 Number of Vehicles Per Mechanic

The computation of this ratio is straightforward. In addition to reflecting changes in efficiency it can be used in determining staffing level requirements as vehicle inventories change. It can also be used in comparing efficiency between jurisdictions if equipment fleet average age are comparable.

6.13 Man-hours per Repair Order

This measure reflects the relative condition of fleet equipment and the labor input required to maintain it. Most

equipment repairs on automotive or administrative use vehicles require eight or fewer mechanic manhours. Repairs on heavy construction equipment may average twelve to sixteen hours per repair. Over maintenance, an aged equipment fleet, inefficient maintenance management for an intensive effort to overhaul and upgrade fleet equipment would be indicated by ratios higher than this. If the latter is the case management probably has made a conscious decision to accept higher maintenance expenses in the short run to achieve greater long term efficiency. This ratio in conjunction with other measures would identify which of the other possibilities is occurring.

16.14 Number of Repairs per Vehicle

This index also reflects fleet condition and labor efficiency. Ideally this ratio should approximate the number of scheduled PM's per vehicle. If the PM cycle is on three month intervals this ratio would be four repairs per vehicle per year. This ratio will most closely approximate the number of scheduled PM's times the unscheduled versus scheduled repair effectiveness measure described above.

The usefulness of this measure in analyzing efficiency comes when analyzed in conjunction with the manhours per repair order index presented in paragraph 16.13. This relationship is displayed in Figure 10. The fleet managers goal should be to operate in the lower left hand quadrant.

		Man Hours per Repair	
		Low	High
Repairs Per Vehicle	High	Inefficient	Very Inefficient
	Low	Very Efficient	Efficient

Figure 10. Relationship of Manhours per Repair and Repairs per Vehicle to Maintenance Efficiency.

An aging equipment fleet would cause performance to shift to the right.

16.15 Actual Manhours versus Standard Manhours

Maintenance standards may be adopted from published flat rate manuals or may be locally developed. Standard manhours should be recorded on the SRO by the equipment inspector. Actual manhours should be recorded on the SRO by the mechanic and verified by the shop foreman. These figures are logged in maintenance control log and totalled at the end of reporting periods.

This ratio should be close to unity. A tolerance of fifteen to twenty percent would be acceptable and allow for repair requirements identified by the mechanic that the inspector could not have detected. If reasonable standards are applied to all repair actions and this index falls within the acceptable range efficient maintenance effort is being pursued.

16.16 Average Downtime per Repair

This ratio when compared to the manhours per repair indicates how efficiently repair actions are processed through the shop. A perfectly efficient system would yield a one to one relationship between average manhours per repair and average downtime per repair. Delays for parts procurement, in inspection and mechanic backlogs, and actual percentage of mechanics' time devoted to breaks, show clean-up, training, and so forth make this goal unattainable. A relationship of two to one (downtime versus repair tie) reflects a reasonable expectation of an efficient new system.

16.17 Cost per Motor Pool Dispatch

The number of dispatches in a reporting period can easily be determined by counting the number of trip tickets issued during the period. These data are available on an overall and individual equipment basis. The cost of operating the motor pool can be derived from accounting records or estimated based on pool composition and average unit costs for this equipment. This index will vary with the type and age of equipment in the pool and acceptable levels should be derived locally. The importance of this index lies in its change over time.

16.18 Summary

The procedures for performance measure computation and use presented result in significant evaluation criteria for motor fleet operations. Their derivation and data sources are relatively simple and for the most part can be obtained using manual recording procedures. Automation of these data would be justified for large inventories and could yield reports on individual vehicles as well as overall performance.

Similar procedures can be developed for other public works service areas to yield the performance measures identified in Part 2 of this report. Operating these evaluation procedures increases the cost of service delivery. The potential benefits in system effectiveness and efficiency far outweigh these costs, especially where current monitoring systems are inadequate or nonexistent. Knowledge of service delivery performance levels can greatly increase public confidence in government expenditure of tax revenues and enable them to make informed decisions on investment and tax rate adjustment made by elected officials or presented to them in referendums. Without them public synicism of government performance will only be fostered.

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APPENDIX A

FAST DIAGRAMMING

Strict application of Function Analysis System Technique (FAST) diagramming would yield diagrams slightly different than presented in the main text of this paper. FAST diagramming aids in analyzing the functions performed by a system, component, or process. Many methods may be available to perform a given function. Performance methods are not discussed in this report. Any method which accomplishes the function in an efficient and effective manner is appropriate. FAST diagramming as used here is a tool to help identify which measures are appropriate to confirm the effectiveness of a method used to perform required functions.

The relative position that an item or function occupies in the scheme of a total system is called its "level of indenture." A university's college of engineering is a component of the university, or, is a indentured element of the university. Likewise, a department of civil engineering is a component of the college of engineering. These relationships would be displayed in a FAST diagram thusly:

University College Department

The highest order indenture level displayed is the university while the lowest order function displayed is the department. This diagram does not depict the total system, however. The university is a component of a broader education system, which is part of a state government system, which is part of an American socio-economic system, and so forth. The civil engineering department also has components including faculty, staff, assistants, students and so forth.

Similar logic also applies to analysis of functional relationships. FAST diagramming rules provide a method of displaying these relationships on paper in an understandable form. Figure A-1 depicts FAST diagramming procedures.

Functions which are shown vertically in the diagram occur either at the same time or all the time. If the function happens at the same time it is placed below the horizontal function path. If it happens all the time it is placed above the horizontal function path at the extreme right. Specific objectives to be kept in mind are displayed in dotted boxes.

Scope lines are used to limit or highlight the problem or system under study. Higher order functions, or desired outcomes, lie to the immediate left of the left scope line. The functions supplying inputs to the system lie to the right of the right scope line. Reading from right to left

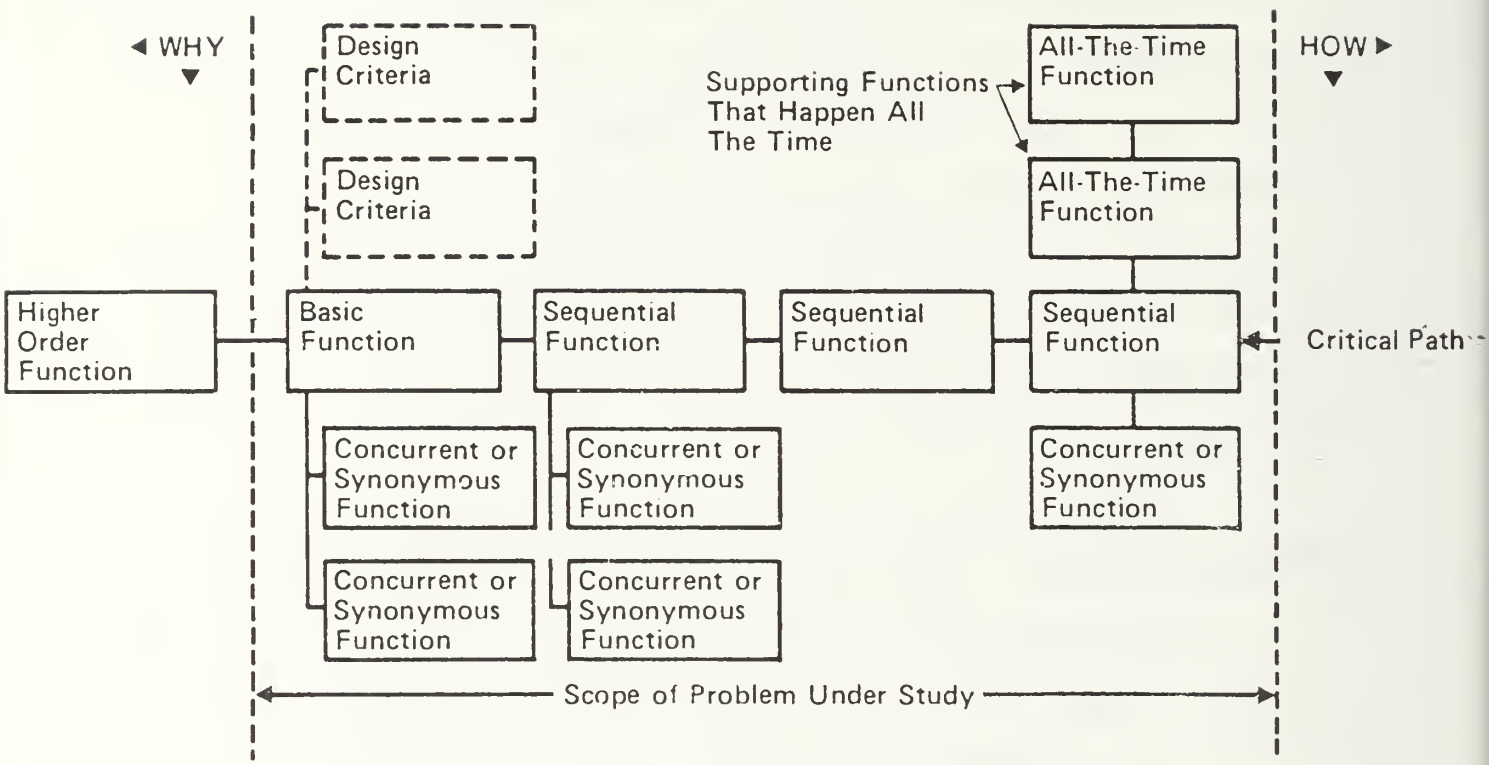

Figure A-1. FAST Diagram Procedures

in the diagram one sees how a preceeding function will be accomplished. Reading from left to right explains why a lower order function is required.

In this report FAST disgraming is used to identify effectiveness measures. Efficiency measures could also have been identified using this technique by expanding the function analysis to the right and shifting the scope lines to lower undenture levels. It was not done as the efficiency measures are readily evident upon examination of service delivery process inputs and outputs.

The FAST diagram for Solid Waste Collection, if FAST diagraming procedures were closely followed would appear as in Figure A-2.

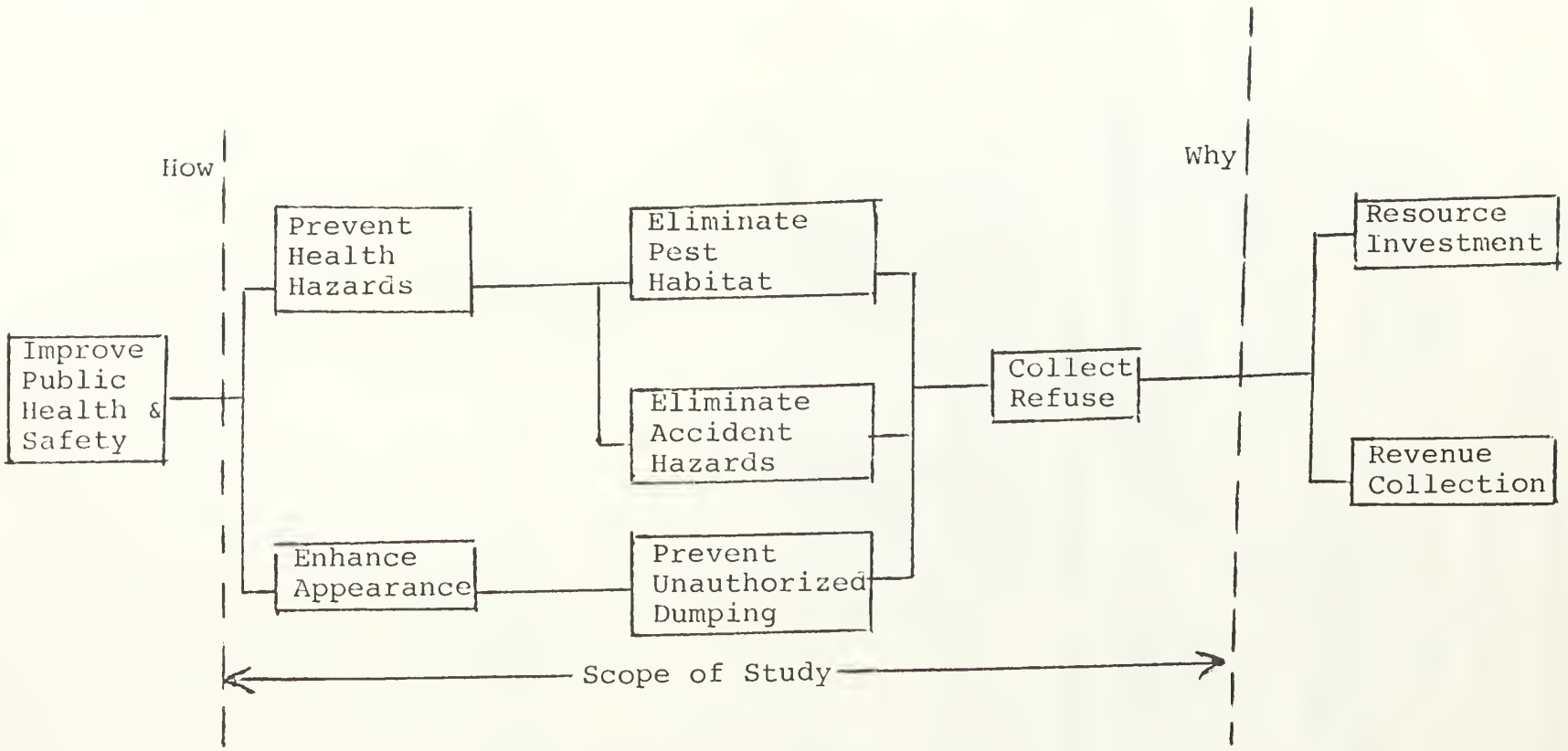

Figure A-2. Revised Solid Waste Collection FAST Diagram

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L27463 Lasham
c.1 Measuring public
works performance.

23 APR 86 33328
30 JUL 87 31855
1 DEC 87 32645

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